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ABSTRACT

Using a textbook entitled "A Survey of Mathematics for College Students Using a Programming Language," an exploratory study was conducted to investigate the effectiveness of using APL and the computer in teaching a survey of mathematics course. The course was taught in two sections: one section was taught using APL, access to a computer terminal, and the above mentioned textbook; the other was taught the same topics using a textbook with comparable content but without APL or the computer. There was no significant difference between the performances of the two sections on a math aptitude pretest or any of the course's exams, including the final exam. Implications of the study include the following: (1) students with no previous background in computer languages or computer usage can be taught APL along with mathematics; (2) students have at least as good an understanding of the concepts of mathematics when they learn using APL as they do when they learn using the conventional way; and (3) in addition to learning at least as much mathematics as non-APL students, APL students learned valuable programming skills and computer concepts. General recommendations and specific suggestions are offered for teachers of survey of mathematics for the integration of computer science instruction in their courses. (CHV)

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TEACHING A SURVEY OF MATHEMATICS FOR COLLEGE STUDENTS USING A PROGRAMMING LANGUAGE

BY

Edward J. LeCuyer

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Teaching a Survey of Mathematics for College Students Using a Programming Language

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Introduction

This manuscript is a description of work done by the author during the academic year 1975-1976, while he was a doctoral student at the School of Education, University of Massachusetts.

The investigation has two major components: (1) A textbook, written by the author, entitled *A Survey of Mathematics for College Students Using a Programming Language*, and (2) an exploratory study into the use of A.P.L. in teaching a survey of mathematics course to college students. It represents one response to the C.U.P.M. plea for experimentation in teaching basic college mathematics using the computer.

In the textbook, a survey of basic topics in mathematics (topics usually covered in a freshman survey course) is presented using A.P.L. notation together with conventional mathematical notation. That is, concepts and algorithms are described using symbols from both notations, usually in parallel. Discussions of applications of all topics are presented, followed by exercises and problems. Computer programs presented in the text are intended to enable the student to observe and experiment with the mathematical concepts and algorithms, and programs for computer solution (i.e., programming projects) are included as optional exercises. This textbook consists of the following chapters: Chapter 1: Set Theory; Chapter 2: Logic; Chapter 3: Vectors and Matrices; Chapter 4; Systems of Linear Equations; Chapter 5: Determinants; Chapter 6: Functions and Graphs; Chapter 7: Exponential and Logarithmic Functions; Chapter 8: Differential Calculus; Chapter 9: Integral Calculus; Chapter 10: Probability; Chapter 11: Statistics; Chapter 12: The Trigonometric Functions; and Appendix.

Using this textbook, an exploratory study was conceived in order to investigate the effectiveness of using A.P.L. and the computer in teaching a survey of mathematics. This study was conducted at the University of Massachusetts in the spring of 1976 for two sections of Math 100: Mathematics in the Modern World, with eighteen students and twenty-seven students (mostly freshmen) respectively. One section was taught using A.P.L., access to a computer terminal, and the above mentioned textbook. The other section was taught the same topics without A.P.L. or the computer using a comparable textbook.[1]

Math 100 is the lowest numbered mathematics course at the University of Massachusetts and is usually taken by students who want three credits in science-mathematics as part of an area requirement. These people normally do not take any further mathematics courses and typically are not very interested in mathematics. Many of them have had difficulty with mathematics in the past. There are no prerequisites for this course, and many students usually have a weak background in mathematics. The students in the author's classes consisted primarily of freshman liberal arts students. On the average, they had a background consisting of from one to one and a half years of high school algebra with an average grade of

C-. Their average college board score in mathematics was in the low 400's. Thus, it could be said that these students represent a challenge to the instructor.

Considering the caliber of student in Math 100, and the fact that the study took place over only one semester, only a subset of the topics in the textbook could be covered. Specifically, the following chapters of the author's textbook were covered in the following order: Chapter 1: Set Theory; Chapter 6: Functions and Graphing; Chapter 7: Exponential and Logarithmic Functions; Chapter 11: Statistics; Chapter 3: Vectors and Matrices; and Chapter 4: Systems of Linear Equations.[2]

Both classes were administered a multiple-choice, diagnostic pretest constructed by the author, and designed to measure their knowledge of the topics to be covered before the start of the course. At the end of each set of two chapters, the classes were given parallel forms of a multiple-choice test prepared by the author. Finally, at the conclusion of the course, both classes were given a final examination, which was actually the same as the pretest. The author attempted to design the tests so that they would measure the understanding of concepts, rather than just computational skills and memory. In fact, on all tests after the pretest, students were allowed to use a one-page reference page of notes which they themselves wrote (sort of a "legal cheat sheet"). This eliminated the need for the students to memorize. The author also attempted to design these tests so that they would favor neither class. The results of these tests are summarized in the table below:

	Mean for the A.P.L. Class (18 students)	*Mean for the Non-A.P.L. Class (27 students)*
Pretest	3.39	4.37
Test 1 on Set theory and Functions	17.11	17.0
Test 2 on Exponential and Logarithmic Functions and Statistics	18.22	16.40
Test 3 on Matrices and Systems of Linear Equations	19.6	18.9
Final Exams	18.5	19.04

As one can see from this table, there was no significant difference between the performances of the two classes on these tests.

In addition to these tests, both classes were given a questionnaire to determine their initial attitudes towards themselves as mathematics students, toward mathematics, and toward the computer. At the end of the course, they were given a second questionnaire designed to measure changes in attitude toward the course, mathematics, and the computer as a result of the course. The questionnaire also attempted to measure final attitudes toward the course, the instructor, the text, and the computer.

Based on the results of these questionnaires, it could be said that the A.P.L. class enjoyed using A.P.L. and the computer to learn mathematics. The students did not find this approach exceedingly difficult, and many felt that the use of A.P.L. and the computer made the course seem more interesting and relevant to them. Many also felt that the use of A.P.L. and the computer helped them to better understand the mathematics. In general, the A.P.L. students reacted very favorably to the use of A.P.L. notation and the computer in learning mathematics.

Implications of the Study

Since this is only a small, one-shot exploratory study and not a large formal experiment, no globally conclusive statements can be made. However, the author does feel that the evidence of this study supports the following implications. These implications merit further study, and the author hopes that further research will be undertaken in each of these areas.

1. Students with no previous background in computer languages or computer usage can be taught A.P.L. along with mathematics.

In general, the students in this exploratory study had little difficulty in learning A.P.L.

and conventional mathematical notations simultaneously. They were able to use A.P.L. and the computer to do their homework. The same amount of mathematics was taught in the usual time, indicating that A.P.L. can be taught along with mathematics without sacrificing very much time from the mathematics.

2. Students have at least as good an understanding of the concepts of mathematics when they learn mathematics using A.P.L. as they do when they learn it the conventional way.

The results of the tests in this exploratory study seem to support this statement. In general, the A.P.L. students did at least as well on these tests as the non-A.P.L. students. Also, many of the A.P.L. students themselves stated that they felt that A.P.L. and the computer helped them to understand the concepts in the course.

3. Students using the A.P.L. approach learn more than students using the conventional approach.

The test results indicate that the A.P.L. students learned at least as much mathematics as the non-A.P.L. students. In addition, they learned a versatile skill—computer programming—and they learned to use a powerful tool—the computer. They learned A.P.L., a very powerful programming language. They learned these computer-related skills without sacrificing the learning of mathematical skills and concepts. Thus, the A.P.L. students learned more than the non-A.P.L. students.

4. The use of A.P.L. and the computer does not detract from the students' ability to do computations.

Since the author does not feel that computational ability is a very important facet of a course such as Math 100, he did not explore this issue thoroughly. However based upon the test questions which required computational ability, it does not appear that the A.P.L. students were significantly less able to perform mathematical computations than the non-A.P.L. students, despite the fact that much of their computations on the homework problems wre done by the computer.

5. Many students enjoy learning mathematics using A.P.L. and the computer.

In general, most of the A.P.L. students reacted favorably to this method of learning mathematics. While there were a few people who indicated that they did not like this method, they were more than offset by people who indicated that they liked this approach. For some people, the use of the computer made a significant difference in their enjoyment of mathematics.

6. Incorporating A.P.L. and the computer in the basic mathematics course is a good way to get students who would not otherwise use the computer to become familiar with this important tool of our modern world.

Many people indicated that they would never have used the computer if it were not for this course. This is true in spite of the fact that on the initial questionnaire they stated that they believe that our present world is largely influenced by computers and that they believe that everyone should know something about the use of the computer. After having used the computer in this course, they indicated that it was not as hard to use as they had imagined it would be, that they enjoyed it, that it made the course more interesting, and that they would use the computer in the future if the need arises. They also indicated that they had a better attitude toward computers at the end of the course than they had in the beginning.

7. The author's textbook can be used effectively to teach a survey of mathematics course using A.P.L.

The author feels that the results of this exploratory study support this statement. However, it should again be pointed out that the author of the text was also the instructor in the exploratory study.

General Recommendations

The author would like to make some recommendations to teachers of college survey of mathematics courses.

1. Use the computer in teaching a college survey of mathematics course.

The computer is rapidly becoming an extremely important and useful tool in our modern world. We are all becoming more and more affected by computers. Therefore, it would seem to be important that all college graduates know something about using the computer. However, many college students will not take a computer course per se. An excellent way of acquainting these people with the computer is by incorporating the computer in the basic mathematics course. This can be done in such a way that the amount of mathematics learned will not be decreased. In fact, by incorporating the computer in the mathematics course, the student may learn the mathematics better and enjoy it more.

2. Use A.P.L. in teaching a college survey of mathematics course.

A.P.L. is an easy to learn, yet extremely powerful and useful computer programming language. It was first developed as a notation for doing mathematics and can be taught very effectively along with the mathematics.

3. Assuming the teacher agrees to use A.P.L. and the computer in teaching his survey of mathematics course, he must then be willing to accommodate his role as a teacher to fit these new, powerful teaching tools.

It may become necessary for the teacher to make some changes in his teaching role and technique in order for the students to benefit fully from the use of the computer and A.P.L. in the mathematics course. With this in mind, the author would like to make some specific suggestions to teachers who would like to use an approach similar to the exploratory study described briefly in this paper. These suggestions are based on the author's experiences in this study.

Specific Suggestions

1. Use A.P.L. notation and conventional mathematical notation in parallel.

This is a new approach to teaching mathematics. However, based on this exploratory study, the author feels it is a good one. Having to translate between the two notations will help strengthen the mathematical concepts for the students. The two notations are compatible enough so that the students will not be confused at learning two notations simultaneously.

2. If possible, have a computer terminal directly available in the classroom.

The author found it rewarding to have a different student seated at the terminal in each class. In this way, the class can see first hand the ease with which mathematics can be done at an A.P.L. keyboard. The student programmer becomes a key part of the class. This makes the rest of the class more alert and active. If a student asks a "what if" question, the student programmer can try out the question on the terminal and get an immediate answer, thereby encouraging experimentation with mathematics. Before any proofs are done in class, several specific examples can be done by a member of the class at the terminal, thereby giving the class confidence in the fact being proved. The computer can do computations very quickly and the class time will be saved because of it.

3. If possible, have a computer terminal available for the students to do their homework outside of class.

The biggest criticism the students in this exploratory study had of using the computer to learn mathematics was of the nonaccessibility of a computer terminal for doing homework. The demand for terminals was great, and the students would sometimes have to wait a long time to get a turn at the terminal. For some students, this inconvenience and waiting time overshadowed the advantages of using the computer to do their homework. If possible, reserve a centrally-located terminal especially for the students in your class.

4. If possible, the instructor or a student assistant should be available to assist the students at the terminal.

This is especially important at the beginning of the course, when the students are more likely to have difficulties at the terminal. In the beginning, the author's students made several errors, and if the instructor had not made himself available at the terminal, some of these students would have

become frustrated and might have given up. After the students have obtained a feel for the terminal and have learned to correct their errors, it will not always be necessary to have an assistant available at the terminal.

5. Strongly encourage the students to try to use the terminal at the beginning of the course.

Getting the students to take that first step at the terminal is very important. Once the students have tried using the terminal and see that it isn't very difficult, they'll be "hooked." However, getting them to take that first step is sometimes difficult. Perhaps the instructor could use the first class or two to have the students take turns experimenting at the terminal. The author found this approach very valuable in getting students over their initial fear and reluctance to use the terminal.

6. Collect homework and write helpful comments on it.

Perhaps this is standard and should be included in any mathematics course. The fact that the instructor is interested enough in the students' homework to read it carefully will lead most students to do a conscientious job on it. It is important that the student take an active role in this course. He learns mathematics by doing it. The student will always do the homework in a course in which it is collected before he will do it in a course where it is not. This is especially true if comments are made on the paper. These comments may be quite helpful to the student in detecting and correcting errors. If there are no errors, the comment "nice job!" will be appreciated by the student.

7. In a computer oriented class, be a little patient with the students about their homework.

Because of difficulties in getting access to a computer terminal and possible difficulties at the terminal, it may not be possible for all students to do the homework immediately. Of course, they should be encouraged not to let the assignments pile up. However, a little tolerance on the time should be allowed.

8. Avoid making students type in long programs.

When typing in long programs, many students will make errors, even if they type in the program successfully, they will become concerned about the amount of time needed to type in the program before they can use it to do the homework. If possible, the instructor could store these longer programs in a common workspace which would be available to the class. However, if the program is short, the student should be encouraged to type it in himself. One wouldn't want the student to view the computer as merely a source of canned programs.

9. With regard to programs, this author would recommend presenting the student with the completed program, plus an explanation of the program and some illustrations of its use.

The emphasis is put on how to use the existing program to do the mathematics involved. The student may be asked to write some programs of his own in some of the exercises. However, in general, he should be provided with programs needed as a foundation for the development of the mathematics.

While the author realizes that by providing already written programs he is perhaps depriving the student of the opportunity to develop the algorithm for doing the particular mathematical operation himself, and of the opportunity to write, debug, and rewrite his own program, it is his belief that the above approach is the appropriate one for the Math 100 type student. The program should be explained so that the student fully understands what it is doing for him. However, the emphasis is put on the mathematics and not on the programming.

10. Finally, this author recommends that the instructor concentrate on mathematics in class.

Don't use class time for discussing programming debugging techniques, etc. Let the students read the appendix or a programming manual and have someone available at the terminal to help the students overcome programming difficulties. Keep in mind that this is a mathematics class and not a programming class. Emphasize the power and usefulness of A.P.L. as a mathematical nota-

tion and tool. Take advantage of this power and usefulness, but don't get distracted by programming details. Introduce the A.P.L. only as needed in the development of the mathematics.

In conclusion, this author found the approach of using A.P.L. and the computer to teach a survey of mathematics to be a rewarding and enjoyable one, and would recommend this approach to others who teach a survey of mathematics to college freshmen. Hopefully, the textbook *A Survey of Mathematics for College Students Using a Programming Language* will be available during 1977 for those in need of a texbook for teaching such a course.

Notes

1. *Mathematics: With Applications in the Management, Natural, and Social Sciences*, by Margaret L. Lial and Charles D. Miller, Scott Foresman Co., 1974.

2. This order of topics was chosen because it corresponds to the order of topics in Lial and Miller's text.

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